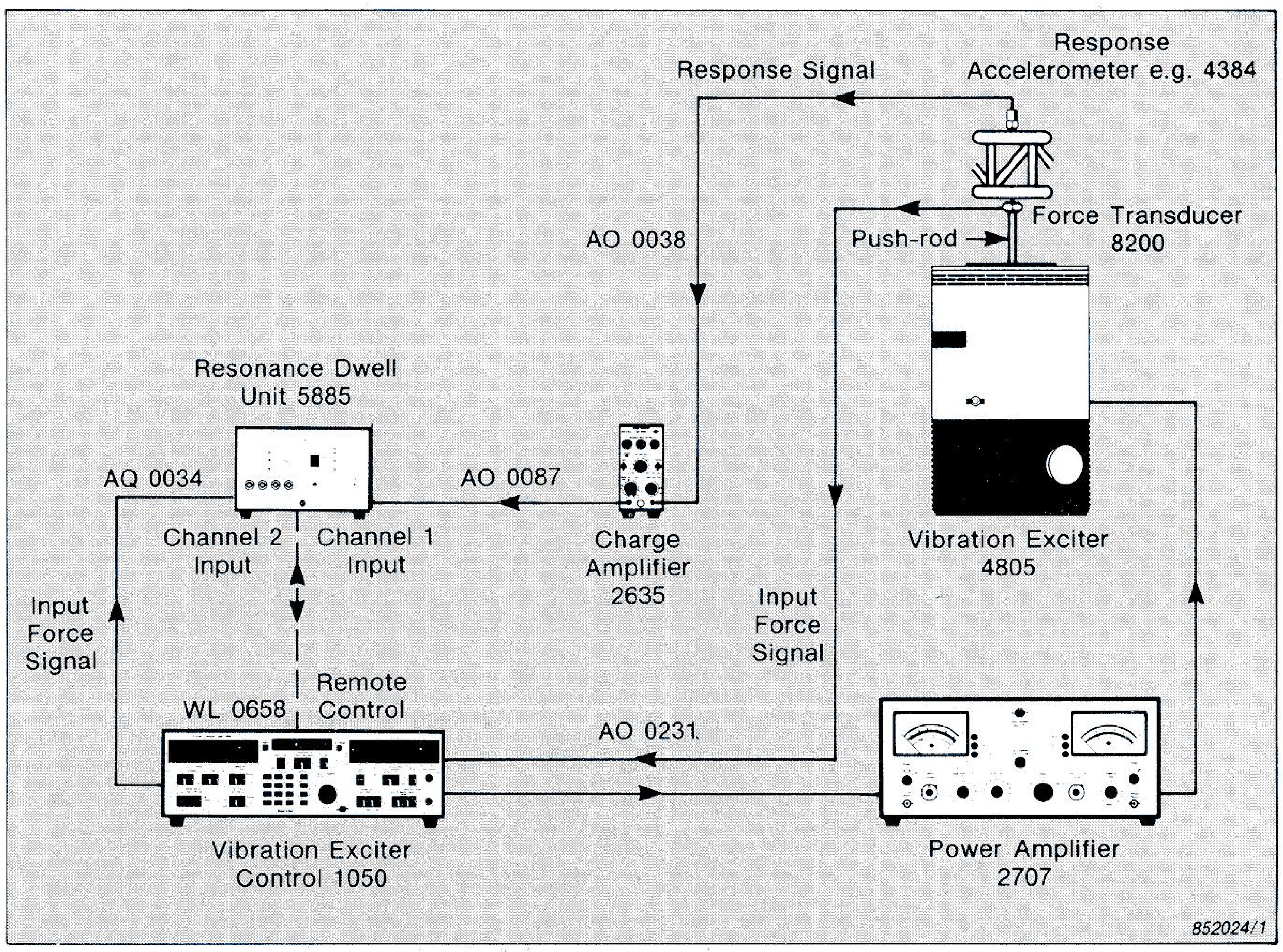
Brüel & Kjær application notes

Resonance Dwell Testing

Environmental testing includes procedures for testing structures and components at their resonance frequencies, in order to provoke fatigue in the test object. During such tests, the resonance frequency will change. In order to ensure that the object is tested at the correct frequency, the excitation has to be tracked, and locked to the critical resonance frequency. This application note describes the instrumentation and procedures used for successful vibration testing at critical frequencies.



An instrumentation set-up for resonance dwell testing, using an accelerometer as the response transducer.

Introduction

Many types of structures, mechanical components, and material specimens are required by industrial and military standards to undergo fatigue testing. One common fatigue test is called *resonance dwell* testing. This is used to test an object continuously at a particular resonance. In principle, this would seem to be a simple task: the frequency and level controls of a vibration exciter system should be adjusted to excite the test object at the required stress level, at the desired resonance. However, in practice, resonance dwell testing puts a number of demands on the instrumentation. The resonance frequency of the test object changes due to progressive fatigue, and for example, temperature effects on the internal damping.

Solving the problems

Problems associated with frequency and output-level instability have been overcome by modern instruments such as the Brüel & Kjær Vibration Exciter Control Type 1050. The 1050 incorporates high-resolution drift-free frequency control, as well as extremely stable vibration and force control.

In particular, in lightly damped test objects, the problem of a varying resonance frequency can be particularly troublesome. It can be solved only if the resonance conditions are accurately monitored, and the excitation frequency is adjusted accordingly.

The Resonance Dwell Unit Type 5885 has been designed to solve the problem associated with a varying resonance frequency of the test object. At resonance, the phase angle between the input force and the response acceleration is ±90°. A small change in frequency results in a large change in the phase angle. When the phase shift between these signals changes, the 5885 activates the frequency sweep of the 1050, adjusting the generator frequency until the phase shift is again ±90°.

The resonance dwell system is shown in the opening figure. In this system, the force and acceleration signals are supplied by a Force Transducer Type 8200 and an Accelerometer Type 4384, respectively. These signals are compared in the 5885. The output of the 5885 is supplied to the 1050, forming a feedback loop which is used to lock the generator frequency to the varying resonance frequency.

Occasionally, the engineer may want to maintain a phase shift other than 90°, for example, if either one of the transducers introduces a phase shift. The addition of a selectable phase-shift stage (option WH 2122) ensures operation under such conditions.

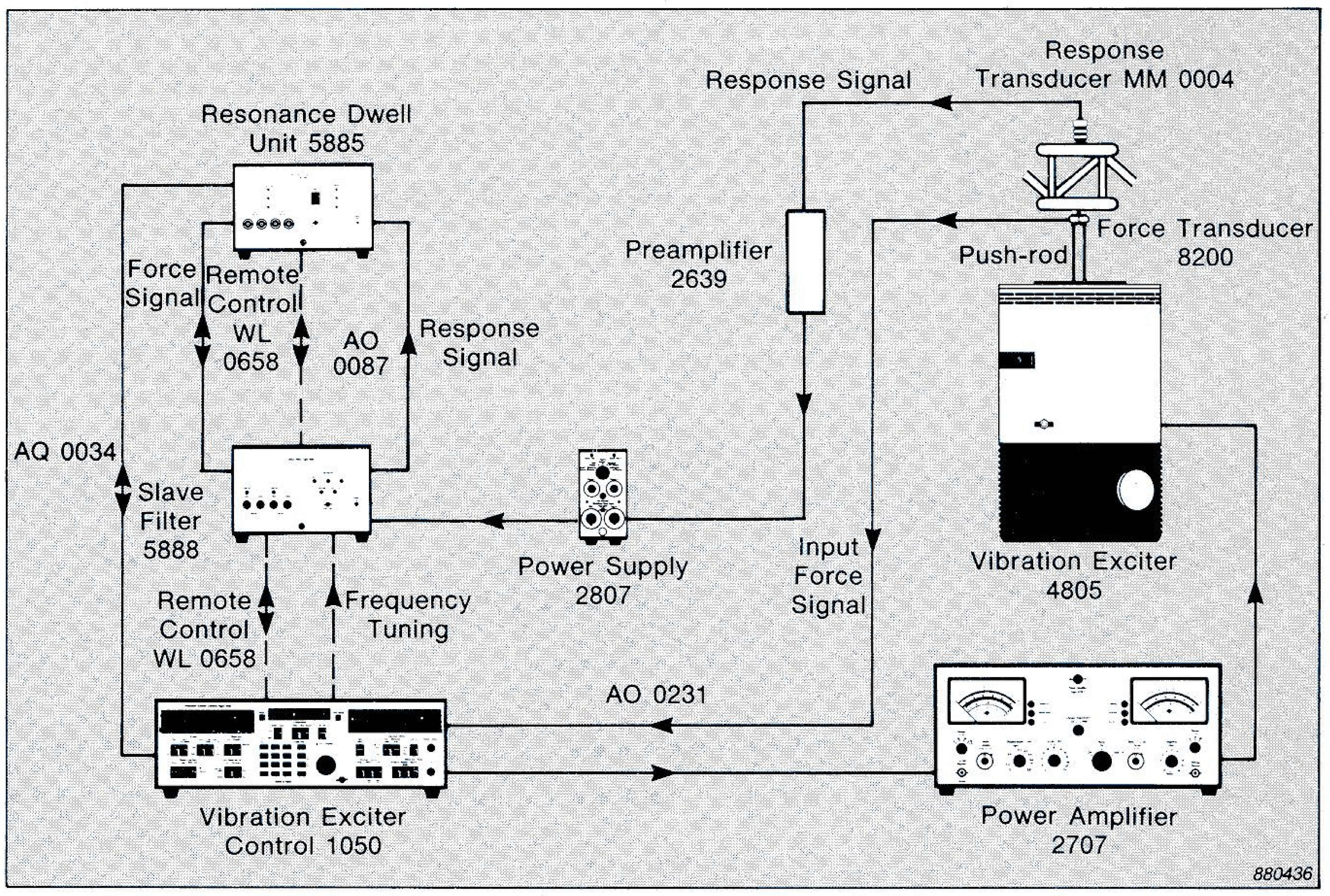


Fig. 1. An instrumentation set-up for resonance dwell testing, using an optical response transducer, and a Slave Filter Type 5888.

Alternative response transducers

For lightweight test objects, the addition of any mass, even that of a very small accelerometer, cannot be tolerated. A non-contact means of measuring the response is essential to prevent detuning the test object.

A Capacitive Transducer MM 0004 measures vibratory displacement without making physical contact. It is well suited to many types of beams, diaphragms and panels. It is used with a microphone preamplifier to provide a signal to the Type 5885. Figure 1 illustrates such an instrumentation set-up.

Since acceleration and displacement are 180° out-of-phase, they will both exhibit a 90° phase shift at resonance. Consequently, they are equally suitable for use with the the Type 5885.

Velocity signals can be used in some applications, but since the phase shift at resonance is not 90°, option WH 2122 must be used.

The Laser Velocity Transducer Type 3544 is another example of a non-contact transducer which can be used to detect the resonance. It incorporates an integrator to produce a displacement signal, which can be used directly with the Type 5885.

Alternative force signals

The level of input force to the test object is measured and kept constant by the 1050. The force signal is also used as an input to the 5885. In the systems shown, the force signal is generated by a Force Transducer Type 8200. The force transducer is connected directly to the test object, and via a push-rod to the vibration exciter. For measurement of large forces, Force Transducer Type 8201 is available.

In some applications, it may be advantageous to obtain a force signal by other means. Since the force generated by a vibration exciter is proportional to the current through the driver coil, a driver-coil current signal may be used to measure and control the force. Brüel & Kjær power amplifiers, such as the Types 2707 and 2708, provide output signals proportional to the driver coil current.

Signal filtering

The system in Figure 1 includes the Slave Filter Type 5888. The 5888 is a two-channel filter used to remove noise and distortion from the force and response signals. Although the inclusion of the slave filter is not essential to the operation of the resonance dwell unit, its use eliminates signal harmonics, and improves resonance detection and tracking accuracy.

Automatic stopping of the test

Often it is necessary to stop the test after a pre-set change in the resonance frequency, for example, before a crack has occurred. By appropriate selection of the sweep limits, the test can be set to automatically stop at a pre-defined frequency. The Vibration Exciter Control Type 1050 can set safety limits around the excitation level, which in combination with the sweep limit, provides a complete safety window for the test.

Control accuracy

The resonance dwell unit tracks the phase at resonance to within ± 5°. Consequently, there can be a small difference between the detected resonance frequency and the true resonance frequency of the test object. However, this is of little importance since the 5° phase deviation corresponds to an amplitude deviation of only 0,38%.

The deviation from the resonance frequency is dependent on the damping as well as the resonance frequency, and can in most case be ignored. For example, for a test item with a Q of 100 and a resonance frequency of 100 Hz, the maximum error would be 40 mHz.

Conclusions

The Vibration Exciter Control Type 1050 plus the Resonance Dwell Unit Type 5885 constitute a fatigue-testing-at-resonance system, by adjusting the excitation frequency, according to changes in the resonance frequency of the test structure.

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